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LABORATORY AND FIELD TESTS OF TOXICITY OF SOME ORGANIC COMPOUNDS TO THE EUROPEAN CORN BORER

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1/ A few of the compounds reported upon were prepared by W. G. Rose, M. S. Schechter, and C. V. Bowen of the Division of Insecticide Investigations.

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INTRODUCTION

Laboratory investigations of organic compounds to establish their toxicities to newly hatched European corn borer larvae were begun at Toledo, Ohio, early in 1938 and continued in 1939 and 1940. Field tests with some of the more promising of these compounds were conducted at the U. S. Department of Agriculture Experimental Farm southwest of Toledo in 1939 and 1940. All the compounds were supplied by the Division of Insecticide Investigations, and the laboratory and field tests were made by the Division of Cereal and Forage Insect Investigations.

LABORATORY TESTS

Methods

As insecticidal control of the corn borer is directed at the young larvae, it having been found extremely difficult to poison the larvae in their later instars, newly hatched larvae were utilized in all laboratory tests reported herein.

The larvae used in the tests were obtained from eggs laid by moths reared in the laboratory from field-collected borers. Usually the borers were retained in cold storage for several months in order to satisfy their diapause requirements and thus provide a continuous supply of moths as needed. Male and female moths were confined in a cylindrical, wire (5 meshes to the inch) oviposition cage 1 foot high and 9 inches in diameter. The side wall of the cage was covered on the outside with coarse cheesecloth, which is not a suitable surface for oviposition, to prevent the escape of the moths from the cage. The top of the cage, which was also of coarse-mesh wire, was covered with a sheet of waxed paper, and the moths readily oviposited on this surface through the wire mesh. The cage was placed under a bell jar to insure the high humidity that is favorable to oviposition.

The paper with the attached egg masses was removed daily, and the sheet cut into small sections, each containing an egg mass. These masses were then placed in a gallon earthenware jar containing moist blotting paper and allowed to incubate. From 20 to 100 egg masses in the "blackhead stage" were required daily when the chemicals were being tested.

Green beet leaves treated with the material under test were used as the feeding medium in early tests. However, extensive decay and disintegration of these leaves contributed to high mortalities among the newly hatched borers confined with them. For this reason cauliflower leaves, which do not decompose so readily as beet leaves, and upon which the borer thrives, were substituted for the beet leaves in the later tests. This change resulted in lower mortalities both on untreated leaves and on leaves that had been treated with a nontoxic material.

The borers were retained under observation for 72 or 96 hours in the early tests. This period later was reduced to 48 hours because it is advantageous in corn borer control to secure a rapid kill. Otherwise the rapid growth of the corn plant tends to expose new, untreated growth at the feeding areas, thus reducing the feeding period on treated surfaces and perhaps allowing the borer to recover by feeding upon the untreated portions of the plant.

The sprays were prepared by grinding with a stirring rod 0.25 g. of the compound in a beaker containing a little water plus all the wetting agent, sodium monosulfonate of butylphenylphenol (Areskap), required to furnish a dilution at the rate of 1 g. of wetting agent to 2,000 cc. of

water in the completed spray. After the material had been finely ground, enough water was added to bring the dilution of the compound to the rate desired.

This preparation was sprayed thoroughly upon fresh green leaves with a small atomizer connected to an air-pressure tank fitted with a low-capacity automatic air regulator set for 10 pounds' pressure. As soon as the surface water had evaporated from the leaves they were made into a small roll and inserted into a test tube containing one or two corn borer egg masses in the "blackhead stage," which just precedes hatching. A cotton-filled cloth stopper was used to plug the mouth of the tube (fig. 1).

Observations were made daily, and, on completion of the test period, records were made of the dead and living larvae, the condition of the leaves, and the amount of feeding that had occurred (fig. 2).

Materials first were tested at the rate of 4 pounds per 100 gallons of water. Those materials that gave high mortality with little or no feeding were retested at either 2 pounds or 1 pound per 100 gallons of water, or both.

Results

All the materials tested in the laboratory and the mortality for each are given in tables 1, 2, and 3.

The compounds reported on have been arranged in groups. This classification is purely arbitrary, as some of the materials could be placed in any one of several groups, but as this system has been used in recording tests of synthetic organic compounds against other insects, it is used in reporting this work.

Table 1.--Results of laboratory tests of some organic compounds used as insecticides against newly hatched European corn borer larvae at a dilution of 4 pounds to 100 gallon of water 1/

ACIDS, ALCOHOLS, AND ESTERS

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Not treated	Amount of feeding 3/
E1204	Benzohydrol	$C_{13}H_{12}O$	133	94.6	3.2	0 - + (a)
E1569	3,4-Methyleneoxybenzal-p-amino benzoic acid	$C_{15}H_{11}NO_4$	307	91.2	2.3	+
E131	4,6-Dinitro-o-cresol acetate	$C_9H_8N_2O_6$	64	89.0	2.0	0 - ++ (a)
E1537	2,4-Dinitrophenol acetate	$C_8H_6N_2O_6$	198	80.3	4.8	0 - ++
E42	9-Fluorenol	$C_{13}H_{10}O$	70	17.1	2.0	++
E1195	Ethyl ester of 4-acetyl-3-hydroxy-2-naphthoic acid	$C_{15}H_{14}O_4$	130	12.2	4.9	+++ (b)
E379	Diphenyl ester of carbonic acid	$C_{13}H_{10}O_3$	128	7.1	3.2	+++ (a)
E1570	3-Methoxy-4-hydroxybenzal-p-aminobenzoic acid	$C_{15}H_{13}NO_4$	127	4.7	0.9	+++
E2211	Benzoyl peroxide	$C_{14}H_{10}O_4$	163	0.6	1.7	+++

AZO, HYDRAZO, AND RELATED COMPOUNDS

E96	p-Iodoazobenzene	$C_{12}H_9IN_2$	80	100.0	2.0	0
E263	p-Bromoazobenzene	$C_{12}H_9BrN_2$	79	100.0	2.0	0
E1207	p-Bromohydrazobenzene	$C_{12}H_{11}BrN_2$	217	99.1	4.9	0 - + (a)

1/ Areskap was used as the wetting agent at the rate of 1 gram in 2,000 cc. of water.

2/ Approximately the same numbers of larvae were used in the nontreated tests.

3/ Symbols denote extent of feeding as follows: 0 = none, + = little, ++ = moderate, +++ = much. The period of tests was 48 hours except as indicated, the letter (a) denoting a 72-hour test period and the letter (b) denoting a 96-hour period.

Table 1. -- Continued

AZO, HYDRAZO, AND RELATED COMPOUNDS (Continued)

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Average percent mortality Not treated	Amount of feeding 3/
E248	Azoxybenzene	$C_{12}H_{10}N_2O$	108	98.2	8.3	+ (a)
E1167	p,p'-Diiodoazoxybenzene	$C_{12}H_8I_2N_2O$	204	36.8	10.7	++ (a)
E1514	1-O-Tolylazo-2-naphthylamine	$C_{17}H_{15}N_3$	117	29.6	2.1	++ (a)
E1168	p,p'-Azobis-(benzoic acid)	$C_{14}H_{10}N_2O_4$	138	26.5	10.7	+++ (a)
E1171	p,p'-Azobisbiphenyl	$C_{24}H_{18}N_2$	124	16.9	10.7	+++ (a)
E1170	p,p'-Hydrazobisbiphenyl	$C_{24}H_{20}N_2$	126	16.4	10.7	+++ (a)
E1171	p,p'-Azobisphenol	$C_{12}H_{10}N_2O_2$	126	12.1	10.7	+++ (a)
E1173	p,p'-Azobisphenetole	$C_{16}H_{18}N_2O_2$	102	11.7	10.7	+++ (a)
E126	1-Phenylazo-2-naphthylamine	$C_{16}H_{13}N_3$	113	9.6	2.1	+++ (a)
E1513	1-Xylylazo-2-naphthol	$C_{18}H_{16}N_2O$	127	4.9	2.1	+++ (a)
E1516	alpha-(o-Nitro-p-anisylazo) -o-acetotoluide	$C_{18}H_{18}N_4O_5$	110	4.0	2.1	+++ (a)
E1513	1-Xylylazoxylazo-2-naphthol	$C_{26}H_{24}N_4O$	179	2.9	2.1	+++ (a)
E1519	1-(o-Nitro-p-tolylazo)-2-naphthol	$C_{17}H_{13}N_3O_3$	132	2.7	2.1	+++ (a)
E453	1-(p-Phenylazophenylazo) -2-naphthol	$C_{22}H_{16}N_4O$	135	2.4	2.1	+++ (a)
E1321	1-(o-Tolylazo)-2-naphthol	$C_{17}H_{14}N_2O$	99	2.4	2.1	+++ (a)
E1520	1-(2,4-Dinitrophenylazo) -2-naphthol	$C_{16}H_{10}N_4O_5$	146	2.2	2.1	+++ (a)
E1516	alpha-(o-Nitro-p-tolylazo) acetoacetanilide	$C_{17}H_{18}N_4O_4$	119	1.2	2.1	+++ (a)
E1518	1-(o-Chloro-p-nitrophenylazo) -2-naphthol	$C_{16}H_{10}ClN_3O_3$	141	1.1	2.1	+++ (a)

Table 1. -- Continued

ALDEHYDES AND KETONES

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality		Amount of feeding 3/
				Treated	Not treated	
E1205	1,5-Diphenyl-3-pentadienone	$C_{17}H_{14}O$	182	5.4	4.9	+++ (b)
E154	3,4-Dichloroacetophenone	$C_8H_6Cl_2O$	189	2.6	1.6	+++
E1559	Dibenzaltriacetophenone (Isomer B)	$C_{38}H_{32}O_3$	239	2.5	2.5	+++
E1557	Benzaldiacetophenone	$C_{23}H_{20}O_2$	220	1.8	2.5	+++
E1543	Dianisal cyclopentanone	$C_{21}H_{20}O_3$	141	1.7	2.6	+++
E1544	Dipiperonal cyclopentanone	$C_{21}H_{16}O_5$	158	1.7	2.6	+++
E1556	Anisalacetophenone	$C_{16}H_{14}O_2$	199	1.3	2.5	+++
E1558	2-Hydroxybenzaldiacetophenone	$C_{23}H_{20}O_3$	229	0.7	2.5	+++
E41	9-Fluorenone	$C_{13}H_8O$	34	0.0	0.0	+++
E156	p,omega-Dichloroacetophenone	$C_8H_6Cl_2O$	48	0.0	0.0	+++

AMINES, AMIDES, IMINES, AND IMIDES

Code No.	Compounds		Number of larvae used in treatment 2/	Treated	Not treated	Amount of feeding 3/
E1456	Acetophenone semicarbazone	$C_9H_{13}N_3O$	85	98.8	5.8	0 (a)
E1462	Benzaldehyde semicarbazone	$C_8H_9N_3O$	84	94.2	5.8	+ (a)
E1505	2,6-Dimethyl-4-heptanone semicarbazone	$C_{10}H_{21}N_3O$	66	93.9	5.8	+ (a)
E1539	p-Chloroacetophenone semicarbazone	$C_9H_{10}ClN_3O$	307	91.2	2.3	+
E1507	p-Methylacetophenone semicar-bazone	$C_{10}H_{13}N_3O$	53	75.5	5.8	++ (a)
	4-Chloro-2-nitrodi-phenylamine	$C_{12}H_9ClN_2O_2$	66	68.2	2.0	++

Table 1. -- Continued

AMINES, AMIDES, IMINES, AND IMIDES --CONT.

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Not treated	Amount of feeding 3/
E1192	Hydrobenzamide	$C_{21}H_{18}N_2$	135	29.1	10.7	+++ (a)
E1469	Carvacryl propionamide	$C_{13}H_{19}NO$	63	17.5	3.9	++ (a)
E1465	N-Xenyl acetamide	$C_{14}H_{13}NO$	49	14.3	3.8	++ (a)
E1466	N-Xenyl propionamide	$C_{15}H_{15}NO$	54	13.0	3.8	++ (a)
E1508	Ethyl methyl ketone semicarbazone	$C_5H_{11}N_3O$	55	10.9	5.8	+++ (a)
E1464	N-Xenyl formamide	$C_{13}H_{11}NO$	65	9.2	3.8	+++ (a)
E1455	Benzophenone semicarbazone	$C_{14}H_{13}N_3O$	126	7.3	4.8	+++
E1527	p-Chlorobenzene sulfonamide	$C_6H_6ClO_2S$	156	7.2	4.8	+++
E1509	Cyclopentanone semicarbazone	$C_6H_{11}N_3O$	79	6.3	5.8	+++ (a)
E2205	N-(o-Nitrophenylmercapto)-p-toluidine	$C_{13}H_{12}N_2O_2S$	169	3.4	1.7	+++
E1468	N-Xenyl pyromucamide	$C_{17}H_{12}NO_2$	65	3.1	3.8	+++ (a)
E1460	Salicylaldehyde semicarbazone	$C_8H_9N_3O_2$	67	3.0	5.8	+++ (a)
E1506	Methyl propyl ketone semicarbazone	$C_6H_{14}N_3O$	68	2.9	5.8	+++ (a)
E1597	S-(o-Nitrophenyl) sulfuramine	$C_6H_5N_2O_2S$	177	2.9	1.6	+++
E1420	2,4,2',4'-Tetrabromodiphenylamine	$C_{12}H_7Br_4N$	72	2.8	3.9	+++ (a)
E1531	alpha-Cyanoacetanilide	$C_9H_8N_2O$	69	2.6	4.8	+++
E1503	4-Methyl-2-pentanone semicarbazone	$C_7H_{15}N_3O$	77	2.6	5.8	+++ (a)
E1467	N-Xenyl benzamide	$C_{19}H_{15}NO$	80	2.5	3.8	+++ (a)

Table 1. — Continued

AMINES, AMIDES, IMINES, AND IMIDES—CONT.

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality: Treated	Average percent mortality: Not treated	Amount of feeding 3/
E1575	Piperonal semicarbazone	$C_9H_9N_3O_3$	100	2.5	0.9	++
E2224	p-Aminobenzophenone semicarbazone	$C_{14}H_{14}N_4O$	123	2.5	3.1	+++
E2220	3,4-Dichloroacetophenone semicarbazone	$C_9H_9Cl_2N_3O$	123	2.4	1.5	+++
E1540	Acetoacetic acid ethyl ester semicarbazone	$C_7H_{13}N_3O_3$	235	2.1	2.3	+++
E1522	Acetonyl acetone disemicarbazone	$C_8H_{16}N_6O_2$	91	2.0	2.1	+++ (a)
E1576	o-Chlorobenzaldehyde semicarbazone	$C_8H_8ClN_3O$	131	2.0	0.9	+++
E1504	Crotanaldehyde semicarbazone	$C_5H_9N_3O$	81	1.9	5.8	+++ (a)
E2221	2,4-Dimethyl-3-pentanone semicarbazone	$C_8H_{17}N_3O$	132	1.9	1.5	+++
E1573	Vanillin semicarbazone	$C_9H_{11}N_3O_3$	116	1.8	0.9	+++
E1420	2,4,2',4'-Tetrachlorodiphenylamine	$C_{12}H_7Cl_4N$	60	1.7	3.9	+++ (a)
E2222	2-Heptanone semicarbazone	$C_8H_{17}N_3O$	138	1.7	1.5	+++
E2245	Cyclohexanone semicarbazone	$C_7H_{13}N_3O$	129	1.7	0.6	+++
E1459	Octanone semicarbazone	$C_9H_{19}N_3O$	61	1.6	5.8	+++ (a)
E2244	Benzil monosemicarbazone	$C_{15}H_{15}N_3O_2$	155	1.3	0.6	+++
E2204	N-Benzal-S-(o-nitrophenyl) sulfuramine	$C_{13}H_{10}N_2O_2S$	156	0.7	1.7	+++
E245	Piperonal oxime ("anti" form)	$C_8H_7NO_3$	37	0.3	0.0	+++
E246	Piperonal oxime ("syn" form)	$C_8H_7NO_3$	44	0.0	0.0	+++
E1571	Vanillin oxime	$C_3H_5NO_8$	143	0.0	0.9	+++

Table 1. -- Continued

AMINES, AMIDES, IMINES, AND IMIDES--CONT.

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Average percent mortality Not treated	Amount of feeding 3/
E270	beta-Anisaldoxime	$C_8H_9NO_2$	30	0.0	0.0	+++
E1523	alpha-Ethylbutraldehyde semicarbazone	$C_7H_{15}N_3O$	61	0.0	2.1	+++ (a)
E1577	Levulinic acid semicarbazone	$C_6H_{11}N_3O_3$	125	0.0	0.9	+++

HYDROCARBONS, HALOGENATED AND NITRO DERIVATIVES

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Average percent mortality Not treated	Amount of feeding 3/
E1355	o-Iodonitrobenzene	$C_6H_4INO_2$	80	100.0	2.0	0
E4	p-Iodonitrobenzene	$C_6H_4INO_2$	80	100.0	2.0	0
E27	1-Nitronaphthalene	$C_{10}H_7NO_2$	84	98.8	2.0	+
E137	Fluorene	$C_{13}H_{10}$	59	98.3	2.0	0 - + (a)
E163	Iodosobenzene	C_6H_5IO	52	84.6	2.0	+ (a)
E203	2,4-Dinitrotoluene	$C_7H_6N_2O_4$	151	30.0	2.0	0 - +++
	p,p'-Diiodobiphenyl	$C_{12}H_8I_2$	69	17.4	2.0	+++
E1181	alpha, beta-Dibromo-beta-nitroethylbenzene	$C_8H_7Br_2NO_2$	96	8.3	10.7	+++ (a)

HETEROCYCLIC COMPOUNDS

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Average percent mortality Not treated	Amount of feeding 3/
E2	Phenazine	$C_{12}H_8N_2$	69	100.0	2.0	0 (a)
E1538	Phenazine oxide	$C_{12}H_8N_2O$	233	100.0	2.3	0
E1208	Isatin	$C_8H_5NO_2$	136	89.9	4.9	+ (b)
E140	Phenoxathiin (phenothioxin)	$C_{12}H_8OS$	55	63.6	2.0	+ - ++ (a)

Table 1. -- Continued

HETEROCYCLIC COMPOUNDS--CONT.

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Not treated	Amount of feeding 3/
E1532	Dehydrobenzoyl acetic acid	$C_{18}H_{12}O_4$	80	16.1	4.8	+++
E1194	4-(2,4-Dinitrophenyl) morpholine	$C_{10}H_{11}N_3O_5$	150	10.6	4.9	+++ (b)
E1532	Dehydroacetic acid	$C_8H_8O_4$	144	6.4	6.0	+++ (a)
E1206	4-Nitrophthalimide	$C_8H_4N_2O_4$	185	5.8	4.9	+++ (b)
E1421	Piperidine-piperidyl dithiocarbamate	$C_{11}H_{22}N_2S_2$	75	4.0	3.9	+++ (a)
E1534	Phenothiazine + 100% excess sulfur		72	3.7	4.8	+++
E1193	4-(4-Nitrophenyl) morpholine	$C_{10}H_{12}N_2O_3$	161	3.6	4.9	+++ (b)
E1544	Dibenzalcyclopentanone	$C_{19}H_{18}O$	232	2.3	2.3	+++
E1545	2,3-Dihydroquinidine-12-carboxylic acid	$C_{13}H_{11}NO_2$	163	2.0	2.6	+++
E2217	N-Fural-S-(o-nitrophenyl) sulfuramine	$C_{11}H_8N_2O_3S$	126	1.5	1.5	+++
E2215	Sulfurized nicotine		133	1.0	1.5	+++
E2218	Thianthrene	$C_{12}H_8S_2$	148	1.0	1.5	+++
E2216	3.7-Dimethylthianthrene	$C_{14}H_{12}S_2$	105	0.9	1.5	+++
E172	Xanthydrol	$C_{13}H_9O_2$	41	0.0	1.5	+++
E173	Xanthone	$C_{13}H_8O_2$	124	4.2	3.5	+++

Table 1. --Continued

SULFIDES, DISULFIDES, AND MERCAPTANS

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality Treated	Average percent mortality Not treated	Amount of feeding 3/
E1197	Di-(3-nitrophenyl) sulfone	$C_{12}H_8N_2O_6S$	125	82.1	4.9	++ (b)
E1536	p,p'-Dichlorophenyl sulfone	$C_{12}H_8Cl_2O_2S$	78	68.6	4.8	0 - ++
E1580	1-(o-Nitrophenylmercapto) -2-naphthol	$C_{16}H_{11}NO_3S$	136	2.2	0.9	+++
E2203	4-(o-Nitrophenylmercapto) resorcinol	$C_{12}H_9NO_4S$	158	1.9	1.7	+++
E1581	Acetonyl-o-nitrophenyl sulfide	$C_9H_9NO_3S$	156	0.6	0.9	+++

PHENOLS AND PHENOL ETHERS

E22	4,6-Dinitro-o-cresol	$C_7H_6N_2O_5$	90	100.0	2.0	0
E375	p-Isopropoxydiphenylamine	$C_{15}H_{17}NO$	70	84.3	2.0	0 - +
E1535	2,4-Dinitroanisole	$C_7H_6N_2O_5$	286	78.5	4.8	0 - ++
E1210	Quinhydrone	$C_{12}H_{10}O_4$	100	31.9	3.2	++ (a)
E1541	Phenoquinone	$C_{18}H_{16}O_4$	251	2.4	2.3	+++
E199	N,N'-Disalicylethylenediamine	$C_{16}H_{16}N_2O_2$	34	0.3	0.0	+++

1/ Areskap was used as the wetting agent at the rate of 1 gram in 2,000 cc. of water.

2/ Approximately the same numbers of larvae were used in the nontreated tests.

3/ Symbols denote extent of feeding as follows: 0 = none, + = little, ++ = moderate, +++ = much. The period of tests was 48 hours except as indicated, the letter (a) denoting a 72-hour test period and the letter (b) denoting a 96-hour period.

Table 2.--Results of laboratory tests of some organic compounds used as insecticides against newly hatched European corn borer larvae at the rate of 2 pounds per 100 gallons of water 1/

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality: Treated	Average percent mortality: Not treated	Amount of feeding 3/	
E1207	p-Bromohydrazobenzene	$C_{12}H_{11}BrN_2$	118	100.0	5.5	0	(a)
E263	p-Bromoazobenzene	$C_{12}H_9BrN_2$	156	100.0	8.3	0 - +	(a)
	2-Chlorofluorene (crude)	$C_{13}H_9Cl$	285	99.3	4.5	0 - +	
E1204	Benzohydrol	$C_{13}H_{12}O$	103	97.4	5.5	+	(a)
E2	Phenazine	$C_{12}H_8N_2$	115	93.9	1.3	0 - +	
E1538	Phenazine oxide	$C_{12}H_8N_2O$	247	93.1	4.5	+	
E248	Azoxybenzene	$C_{12}H_{10}N_2O$	87	85.7	8.3	+	(a)
E1456	Acetophenone semicarbazone	$C_9H_{13}N_3O$	92	76.2	6.1	++	(a)
E1505	2,6-Dimethyl-4-heptanone semicarbazone	$C_{10}H_{21}N_3O$	95	61.0	6.1	+	(a)
E1535	2,4-Dinitroanisole	$C_7H_6N_2O_5$	109	50.4	4.5	+++	
E1539	p-Chloroacetophenone semicarbazone	$C_9H_{10}ClN_3O$	141	47.2	4.5	+++	
E1507	p-Methylacetophenone semicarbazone	$C_{10}H_{13}N_3O$	86	41.6	6.1	+++	(a)
E1537	2,4-Dinitrophenyl acetate	$C_8H_6N_2O_6$	161	28.2	4.5	++ - +++	
E1462	Benzaldehyde semicarbazone	$C_8H_9N_3O$	94	28.2	6.1	+++	(a)
E1197	Di-(3-nitrophenyl) sulfone	$C_{12}H_8N_2O_6S$	69	27.6	5.5	+++	(a)
E1208	Isatin	$C_8H_5NO_2$	99	4.2	5.5	+++	(a)

1/ Areskap was used as the wetting agent at the rate of 1 gram to 2,000 cc. of water.

2/ Approximately the same number of larvae was used in the nontreated tests.

3/ Symbols denote extent of feeding as follows: 0 = none, + = little, ++ = moderate, +++ = much. The period of test was 48 hours except as indicated by letter (a) denoting a 72-hour period of test.

Table 3.--Results of laboratory tests of some organic compounds used as insecticides against newly hatched European corn borer larvae at the rate of 1 pound per 100 gallons of water 1/

Code No.	Compounds		Number of larvae used in treatment 2/	Average percent mortality: Treated	Average percent mortality: Not treated	Amount of feeding 3/
E263	p-Bromoazobenzene	$C_{12}H_9BrN_2$	167	100.0	4.5	0
	p-Iodonitrobenzene	$C_6H_4INO_2$	92	100.0	4.5	0
E22	4,6-Dinitro-o-cresol	$C_7H_6N_2O_5$	93	100.0	4.5	0
E137	Fluorene	$C_{13}H_{10}$	98	100.0	4.5	0 - +
	2-Chlorofluorene (crude)	$C_{13}H_9Cl$	396	99.3	3.0	0 - +
E1204	Benzohydrol	$C_{13}H_{12}O$	93	81.7	4.5	+
E96	p-Iodoazobenzene	$C_{12}H_9IN_2$	100	79.0	4.5	0 - +
E1538	Phenazine oxide	$C_{12}H_8N_2O$	138	62.3	4.5	+++
E248	Azoxybenzene	$C_{12}H_{10}N_2O$	30	60.0	8.3	++ (a)
E1456	Acetophenone semicarbazone	$C_9H_{13}N_3O$	92	20.0	8.7	+++ (a)
E1505	2,6-Dimethyl-4-heptanone semicarbazone	$C_{10}H_{21}N_3O$	106	16.1	8.7	+++ (a)
E1536	p-Chloroacetophenone semicarbazone	$C_9H_{10}ClN_3O$	100	2.0	4.5	+++

1/ Areskap was used as the wetting agent at the rate of 1 gram to 2,000 cc. of spray.

2/ Approximately the same numbers of larvae were used in the nontreated tests.

3/ Symbols denote extent of feeding as follows: 0 = none, + = little, ++ = moderate, +++ = much. The period of tests was 48 hours except as indicated, the letter (a) denoting a 72-hour test period.

Discussion

Although these laboratory tests show the mortality produced by the materials, they do not show in what manner the larvae were killed. As the larvae were partially sealed in a tube, mortality may have been due to stomach poisoning, fumigation, or starvation. In the last case the larvae may have been repelled by an odor or taste and refused to feed. Indications of a repellent action were observed in some of the tests in the "amines, amides, imines, and imides" group, practically all of the larvae migrating away from the sprayed leaves, congregating at the top of the tube, and remaining there for most of the period of observation.

Fumigation effect was indicated when leaves sprayed with some materials from the group of "hydrocarbons, halogenated and nitro derivatives" prevented eggs in the "blackhead stage" from hatching in repeated tests. Larvae which did hatch in tests with these materials were killed within a short time and before any feeding occurred.

The materials giving 100-percent mortalities at dilutions of 4 pounds per 100 gallons of water, with no apparent feeding, were as follows: p-Bromoazobenzene, p-iodoazobenzene, o-iodonitrobenzene, p-iodonitrobenzene, phenazine, phenazine oxide, and 4,6-dinitro-o-cresol. Those which gave approximately 100 percent with little feeding at the same concentration were: p-Bromohydrazobenzene, 99.1 percent; azoxybenzene, 98.2 percent; 1-nitronaphthalene, 98.8 percent; and fluorene, 98.3 percent.

When tested at the rate of 1 pound of material to 100 gallons of water, the following materials continued to give very high mortalities: p-Bromoazobenzene, p-iodonitrobenzene, fluorene, 4,6-dinitro-o-cresol, and 2-chlorofluorene (crude). All caused 100-percent mortalities excepting the last one, which gave 99.3 percent.

From an examination of tables 2 and 3 it appears that the most toxic compounds have come from the "azo" and "nitro derivatives and halogenated" groups. Those materials showing high toxicity in the "amines, amides, imines, and imides" group seem to lose their toxicity much more rapidly upon dilution than those from the above groups.

FIELD TESTS

Methods

Some of the materials showing the most promise in the laboratory tests were given field trials in 1939 and 1940. Five replications of each treatment were included in a random block plot arrangement in a planting of early market sweet corn, each replicate plot being 4 rows wide and 26 feet long. A wheelbarrow sprayer, equipped with a small gasoline engine and a single spray rod and

nozzle with a 16-foot hose, was used in making the applications. A schedule of 4 applications at 5-day intervals, beginning with the first hatch, was followed. Ten consecutive plants from each of the 2 middle rows of each plot were dissected to obtain data on the effects of treatments. The first 3 plants at the ends of the rows were left as buffers.

In 1939, as only limited quantities of the materials were available for the field tests, they were applied at the low rate of 1 pound of material to 100 gallons of water, supplemented by a wetting agent (Areskap) at the rate of 1 part to 2,000 parts of water. In 1940 the applications were made at the rate of 3 pounds of the material per 100 gallons of water, plus Areskap at the rate of 1 part to 2,500 parts of water.

Results

The results of the field tests of 1939 are shown in table 4 and of the field tests of 1940 in table 5.

Table 4. -- Results of the field tests of 1939 against the European corn borer

Code No.	Materials 1/	Pounds per 100 gallons	Percent reduction of borers in treated plants over plants not treated
	2-Chlorofluorene	1	67.9
E249	Azobenzene	1	59.1
E22	4,6-Dinitro-o-cresol	1	55.0
E96	p-Iodoazobenzene	1	49.1
263	p-Bromoazobenzene	1	46.0
	p-Iodonitrobenzene	1	44.4
E137	Fluorene	1	43.7
E1204	Benzohydrol	1	39.8
	Ground derris (standard treatment)	4 (approximately 4% rotenone)	93.8

1/ Areskap was added to each of the above treatments at the rate of 1 part to 2,000 parts of water.

Table 5. — Results of the field tests of 1940 against the European Corn borer

Code No.	Materials 1/	Pounds per 100 gallons of water	Percent reduction of borers in treated plants over plants not treated
E 249	Azobenzene	3	74.9
E2	Phenazine	3	74.4
E1538	Phenazine oxide	3	58.9
	Ground derris (standard treatment)	4 (4.7% rotenone)	94.1

1/ Areskap was added to each of the above treatments at the rate of 1 part to 2,500 parts water.

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Table 6. — Plant tolerance of organic compounds used in the field tests of 1939 and 1940

Code No.	Materials	Pounds per 100 gallons	Tolerance
	2-Chlorofluorene	1	No injury
E249	Azobenzene	1	Slight injury consisting of yellow blotches in whorls
E22	4,6-Dinitro-o-cresol	1	Burned severely, stunted plants, completely destroyed many leaves
E96	p-Iodoazobenzene	1	No injury
E263	p-Bromoazobenzene	1	No injury
	p-Iodonitrobenzene	1	No injury
E 137	Fluorene	1	No injury
E1214	Benzohydrol	1	No injury
E249	Azobenzene	3	Slight injury, bleached unrolled leaves in whorl
E2	Phenazine	3	Very severe injury, plots nearly a total loss
E1538	Phenazine oxide	3	Very severe injury, plots nearly a total loss
	Ground derris 1/	4	No injury

1/ Rotenone content of derris used in 1939 was 4 percent, and in 1940, 4.7 percent.

Discussion

While of the materials tested in the field, 2-chlorofluorene, azobenzene, 4,6-dinitro-o-cresol, and phenazine gave the highest reductions in borer populations, at the concentrations tested, none of them provided as satisfactory protection to the corn plant as derris, the standard for comparison. In addition, a number of the materials caused more or less injury to the corn plant, as shown in table 6, whereas no injury resulted from the derris applications.

It may also be noted (tables 1 to 5, inclusive) that larval mortalities following field applications were generally lower than those caused by the same materials in the laboratory tests. This condition may be associated with (1) a smaller proportion of the feeding area in the field being covered with the materials due to the rapid growth of the corn plant, (2) less opportunity for fumigation effect on the exposed corn plants than in the closed tubes, (3) varying proportions of the newly hatched larvae being exposed to the immediate effects of the treatments due to migration habits of the borer and residue losses from weather effects, more resistant older larvae being thus exposed to the insecticidal residues, or (4) the loss of toxicity from volatilization of the material when exposed in the field. Nevertheless, the performance of 2-chlorofluorene when used at 1 pound to 100 gallons of water was very promising (67.9 percent reduction in borers) and, as its use was accompanied by no plant injury, it is probably the most outstanding of the new compounds tested to date. While no reports of any harmful effects have been received from various entomologists testing the material, it is suggested that suitable precautions be observed in its use pending the results of extensive pharmacological tests which are now being conducted.

The optimum concentrations of the organic compounds have not been determined, and further tests of the more promising materials at higher concentrations are necessary prior to final evaluation of their insecticidal effectiveness. It is probable that if the tests of 1939 had been conducted at the rate of 3 pounds to 100 gallons of water a much higher mortality would have resulted.

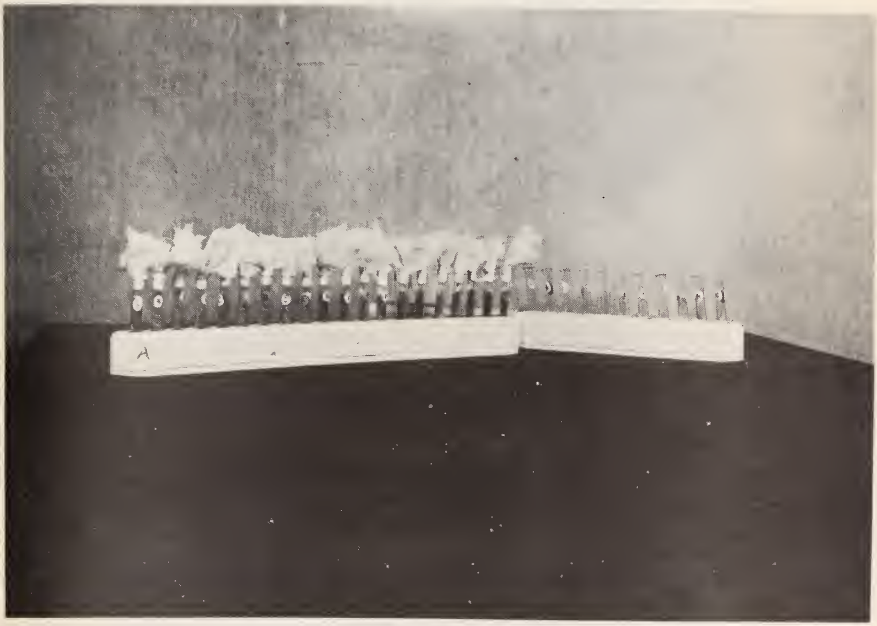

Figure 1.--Cages used in laboratory toxicity texts against the European corn borer.

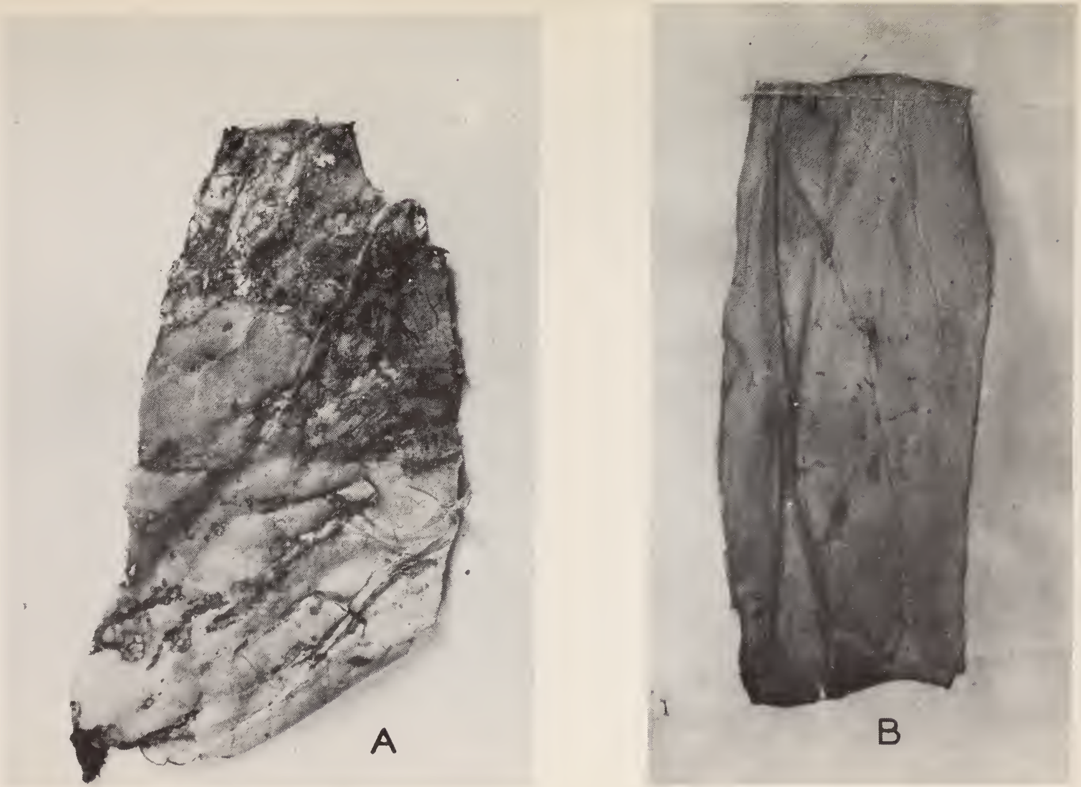

Figure 2.—Cauliflower leaves after a 48-hour test. A, showing heavy feeding and living larvae on nontreated leaves; B, showing no feeding and dead larvae following treatment with 2-chlorofluorene, a compound highly toxic to the borer.